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Spatial forms and mental imagery

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ABSTRACT

Four studies investigated how general mental imagery might be involved in mediating the phenomenon of 'synaesthetic' spatial forms – i.e., the experience that sequences such as months or numbers have spatial locations. In Study 1, people with spatial forms scored higher than controls on *visual* imagery self-report scales. This is consistent with the suggestion that strong general imagery is at least a necessary condition to experience spatial forms. However self-reported *spatial* imagery did not differ between groups, suggesting either that the spatial nature of forms is mediated by special synaesthetic mechanisms, or that forms are depictive visual images rather than explicit spatial models. A methodological implication of Study 1 was that a general tendency for people with spatial forms to use imagery strategies might account for some of their previously-reported behavioural differences with control groups. This concern was supported by Studies 2–4. Normal participants were encouraged to visually image the months in various spatial layouts, and spatial associations for months were tested using left/right key presses to classify month names as belonging to the first or second half of the year (Studies 2–3) or as odd/even (Study 4). Reaction times showed month-SNARC (Spatial Numerical Association of Response Codes) effects of similar magnitude to previously-reported data from spatial form participants (Price and Mentzoni, 2008). Additionally, reversing the spatial associations within instructed images was sufficient to reverse the direction of observed month-SNARC effects (i.e., positive *vs* negative slope), just as different spatial forms were previously shown to modulate the direction of effects (ibid.). Results challenge whether previously observed behavioural differences between spatial form and control groups need to be explained in terms of special synaesthetic mechanisms rather than intentional imagery strategies. It is argued that usually strong general imagery processes should complement synaesthetic mechanisms as possible explanations of spatial forms.

1. Introduction

When thinking about members of certain ordinal sequences – e.g., calendar months, week days, numbers, or historical dates – some people report an involuntary sensation of the sequence member occupying a precise extended area of space, which is in turn part of a larger spatial pattern of sequence members. These so-called *spatial forms* can be experienced in imaginal space, or projected into peripersonal space. They range from simple lines or regular circular patterns (e.g., for the months), to much more complex and idiosyncratic 3D patterns which as Galton (1881, p. 87) observed can assume 'the most grotesque variety of shapes'.

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Recent experiments on spatial forms have tended to approach the phenomenon from the perspective of synaesthesia research (Price and Mentzoni, 2008; Sagiv et al., 2006; Seron et al., 1992; Smilek et al., 2007). Spatial forms appear to share core characteristics of synaesthesia outlined by Ward and Mattingely (2006), namely the involuntary triggering of a consistent extra perceptual sensation – in this case a visuo-spatial sensation – that seems quite alien to the majority of people who do not experience it. From the synaesthesia perspective, spatial forms might derive from abnormal mechanisms such as additional connectivity between cortical areas involved in representing the synaesthetic inducer and concurrent, as is now established for other types of synaesthesia (Rouw and Scholte, 2007). For example, spatial forms may be an exaggeration, and perhaps a distortion, of the general but normally more unconscious neural overlap between parietal systems for spatial and magnitude representation (Hubbard et al., 2005b; Piazza et al., 2006). This is the majority view adopted by papers in this special issue (Hubbard et al., 2009, this issue; Jarick et al., 2009a, this issue, 2009b, this issue; Simner et al., 2009, this issue; Ward et al., 2009, this issue). An alternative synaesthetic theory is that spatial forms arise from cross-talk between cortical areas that mediate representation of ordinal categories (right middle temporal gyrus, rMTG) and proximal object representation areas in inferior temporal lobe (Eagleman, 2009, this issue).

By contrast, early descriptive work on spatial forms at the turn of the 19th century placed the phenomenon within the general context of individual differences in mental imagery (e.g., Galton, 1880a; Phillips, 1897). From this historically older perspective, spatial forms can be considered to derive from the use of visuo-spatial imagery as a childhood mnemonic to help learning of abstract sequences such as numbers or months of the year. This could be a normal strategy whose legacy is sometimes preserved into adulthood as highly automatised visual images (Galton, 1881; Sagiv et al., 2006). Alternatively spatial forms might develop as a compensatory strategy in children who have particular problems in learning these sequences in a purely verbal code (Seron et al., 1992). In either case, the tendency to develop spatial forms could be driven by a general tendency to experience particularly strong visuo-spatial imagery across all domains.

Since the synaesthesia and imagery perspectives both predict highly automatised associations between mental representation of sequence members and space, they are not easily disambiguated by recent behavioural studies of spatial forms which focus on validating the reality and automaticity of peoples' reported spatial associations (e.g., Piazza et al., 2006; Price and Mentzoni, 2008; Sagiv et al., 2006; Smilek et al., 2007). However, the two perspectives are not mutually exclusive. Childhood imagery strategies within a specific domain could be enhanced by genetic predisposition for synaesthetic tendencies. And even if synaesthetic neural connectivity contributes to spatial forms, spatial forms are conscious visuo-spatial experiences and so must involve the brain mechanisms of imagery and visuo-spatial working memory in some manner. Therefore, even from the synaesthesia perspective, it is regrettable that there has been little recent attempt to understand the relation of spatial forms to general mental imagery. This paper tests two related hypotheses that in particular seem to have been neglected: (1) people who experience spatial forms might have unusually strong mental imagery experience in general and, (2) exaggerated use of imagery strategies by spatial form groups might contaminate behavioural comparisons with control groups, or even fully account for observed differences with control groups.

Under the first hypothesis, spatial forms might be merely one manifestation of a more general imagery tendency, or might at least be reliant on a background of strong general imagery experience. In addition to the longstanding literature on individual differences in the everyday experience of mental imagery, there are specific reasons to take this hypothesis seriously. Barnett and Newell (2008) have already reported higher than average self-rated imagery experience among grapheme–colour synaesthetes than non-synaesthetes. Since the incidence of spatial forms is especially high (approx. 60%) among grapheme–colour synaesthetes (Sagiv et al., 2006), it is obvious to ask whether strong imagery is also a characteristic of spatial forms. Although Barnett and Newell (2008) maintained that grapheme–colour synaesthesia should not be dismissed as merely a consequence of strong mental imagery, the distinction between normal and synaesthetic imagery seems considerably muddier for spatial forms. First, the essential description of spatial forms is as some kind of visuo-spatial image that people also often report being able to zoom into and explore. Second, it has long been noted (Phillips, 1897) that spatial forms are continuous with sensations found in most people and that what is classified as a form depends rather on one's criteria. Third, informal observation suggests that people who report spatial forms often seem to experience rich general mental imagery.

If spatial forms are associated with generally strong imagery experience, then it is important to specify more precisely the type of imagery that is involved. In the tradition of mental imagery research, exemplified by the work of Kosslyn and colleagues (e.g., Kosslyn, 2005; Reisberg et al., 2003), *spatial* images represent the layout of a pattern in terms of the explicit relative spatial positions of its component parts, whereas *visual* images depictively represent the so-called *object properties* of a shape, i.e., overall shape and surface properties, in terms of higher order patterns such as contours, surface textures and colours. In an extension of this tradition, Kozhevnikov et al. (2005) have attempted to characterise the style of imagery that dominates in any particular person. Spatial visualisers are argued to encode and process images analytically, part by part, allowing this part structure to be made explicit and enhancing the ability to make dynamic image transformations. By contrast, object visualisers tend to encode images globally as a single perceptual unit, and are faster and more accurate in visual memory tasks, perhaps because the time needed to generate or activate these more holistic images is less dependent on image complexity. Imagery style is relevant to understand the nature of spatial forms, since the distinction between spatial and visual imagery stresses both neural and representational differences with implications for the properties of spatial forms and the manner in which they could be used as a cognitive tool.